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Electron Beam Welding of Thick Cross-Section Copper With Minimal Porosity*

We have developed Electron Beam Welding techniques for joining ≈ 3/4" (19mm) thick OFE copper cross-sections with minimal porosity in RF Cavity assemblies**.** Electron Beam Welding is increasingly being specified for structural welds in copper accelerator components; however, the PEP-II high-energy particle accelerator at the Stanford Linear Accelerator Center uses 26 RF Cavities with smooth interior surfaces finish-machined after welding to ultra high vacuum requirements. Porosity at the finished RF surface can result in potential virtual leaks and possible arc initiation points that can degrade the ultra high vacuum performance of the cavity during operation.

Our initial objective was to confine the root porosity in the 0.08 (2 mm) material to be removed from the cavity body's interior surface during subsequent machining operations. Test results were inconsistent, indicating unacceptable risk with this welding technique. Additionally, we realized that the root porosity migrates up through the weld joint as the beam is ramped off, making strategic positioning of the taper off zone necessary to repair voids that appeared in the final surface.

Geometry and fabrication constraints require separate welding techniques for the various fabrication steps. We have developed three welding techniques for joining the various parts of the assembly: "sacrificial backing-bar", "blow-through", and "cosmetic wash-weld". A sacrificial backing-bar is used to make the circumferential girth weld when joining the two halves of the cavity at its equator. The cosmetic wash-weld technique is used to attach "HOM Ports" and "Beam Ports" from the inside of the cavity. The blow-through technique is used to attach "Equatorial Ports" from the outside of the cavity.

1) Girth Weld

Weld parameters were developed to bury the root porosity in a 0.5” (12.5mm) thick sacrificial backing-bar located on the exit side of the weld joint. The backing-bar was removed during subsequent machining operations. Representative test specimens showed virtually no porosity when machined to the finished surface, but potential porosity in the taper off area became a concern. We centered a port penetration over the weld taper-off area (overlap of the beginning and end of the weld) in a prototype cavity, and removed a core sample. Radiographic analysis of the area indicated a uniform trail of porosity moving from the backing-bar toward the surface as anticipated.

2) HOM & Beam Ports

Three HOM ports are attached from the inside using a 75% penetration structural weld followed by a cosmetic wash-weld. The wash-weld uses a very diffuse beam that gently “stirs” the weld pool, resulting in a smooth, uniform surface. No porosity was visible in the weld taper-off area after finish machining. Two Beam port assemblies are attached, after finish machining the interior of the cavity, using a 75% structural weld from the outside followed by a cosmetic wash-weld from the inside.

3) Equatorial Ports

Fabrication constraints precluded the use of the previous two welding techniques to control porosity. We theorized that the root porosity could be “blown through” the weld joint from the outside when attaching the 6 Equatorial ports. This process requires the beam to over penetrate the joint, necessitating the incorporation of a beam stop in the fixture. The weld overlap area was the only problem, and is positioned so that the pit (0.03” x 0.01” x 0.01” deep) uncovered during finish machining can be sealed with a cosmetic wash-weld. These small imperfections are preferable to leaving the small pits in the final RF surface.

We chose Electron Beam Welding technology for the more than 300 inches of weld joints to optimize the fabrication sequence for these 400 lb. copper assemblies. We are able to successfully join thick copper cross sections with minimal porosity at the internal surface of RF Cavity assemblies by using Electron

Beam welding techniques developed for the PEP-II project. The “sacrificial backing bar”, “cosmetic wash-weld”, and “blow-through” welding techniques have been optimized and successfully implemented in the production operation underway at the Lawrence Livermore National Laboratory. PEP-II is a scientific collaboration between the Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and Stanford Linear Accelerator Center for the US Department of Energy.

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